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(54) ROBOT OPERATION METHOD THAT CAN BE MANUALLY CORRECTED.

(57) A robot operation method which enables the teach point taught in advance to the robot to be easily and manually corrected during the automatic operation of robot and which further enables the required robot operation to be correctly and efficiently executed without using visual sensor. After the automatic operation mode is switched to the manual operation mode (S1, S2) upon reading a predetermined instruction code from a program, the robot tool positioned to a first teach point is shifted to a first work position on the work to compensate the deviation of teach point caused by the deviation of work position (S3) being controlled by a unit that responds to a remote operation board manipulated by an operator, and correction data that indicate the result of manual adjustment are calculated relying upon the input of external signals produced by the manipulation by the operator and are stored in a memory (S4, S5). After the robot's work is completed at the first work position, the second and subsequent teach points are successively corrected based on the correction data upon reading the position correction instruction codes from the program, and the work by the robot is correctly executed at the second and subsequent work positions on the same work.

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SPECIFICATION

ROBOT OPERATING METHOD CAPABLE OF MANUAL CORRECTION

Technical Field

The present invention relates to a robot operating method, and more particularly, to a robot operating method capable of easily performing manual correction of a teaching point during an automatic robot operation, which point is taught to a robot beforehand, and of accurately and effectively performing a desired robot working without the need of employing a visual sensor.

Background Art

It is known to use a robot to carry out working to a workpiece which is transferred along an assembly line and then positioned at a predetermined location on the assembly line. In this case, if the positioning location of the workpiece varies, accurate robot working cannot be carried out even when the robot is operated at an operating position (teaching point) which is previously taught to the robot.

To this end, conventionally, dislocation of the teaching point attributable to positional dislocation of the workpiece is compensated for on the basis of a correction data, which is calculated based on an actual workpiece position detected by a visual sensor and which indicates the error between the actual workpiece position and a reference workpiece position. However, according to the above-mentioned conventional robot operating method, the visual sensor is essentially required, which entails inconvenience.

Disclosure of the Invention

The object of the present invention is to provide a robot operating method capable of easily performing manual correction of a teaching point during an

automatic robot operation, which point is taught to a robot beforehand, and of accurately and effectively performing a desired robot working without the need of employing a visual sensor.

To achieve the above-mentioned object, a robot operating method according to the present invention comprises the steps of: (a) operating a robot in a manual operation mode when a first command code is read out from a program during an automatic robot operation; (b) restarting the automatic operation when a predetermined external signal is supplied during the manual operation, and calculating and storing a correction data indicative of a manual adjustment amount in the manual operation; and (c) correcting a teaching data, read out from the program, in accordance with the correction data when a second command code is read out from the program after the restart of the automatic operation.

As mentioned above, according to the robot operating method of the present invention, the robot is manually operated when the first command code is read out, and the teaching data is corrected on the basis of the correction data, calculated at the time of restarting the automatic robot operation, when the second command code is read out after the restart of the automatic operation. Accordingly, the robot can be manually operated at an appropriate time point during the automatic operation so that a desired manual adjustment is easily carried out, by the use of a program in which the first and second command code are respectively stated at required portions of the program. In addition, the teaching data can be corrected in accordance with the results of the manual adjustment, without the need of employing a visual

sensor.

Brief Description of the Drawings

Fig. 1 is a schematic block diagram showing a robot to which a robot operating method according to an embodiment of the present invention is applied;

Fig. 2 is a flowchart showing an operation of the robot of Fig. 1; and

Fig. 3 is a view showing correction of a teaching point, carried out by the robot.

Best Mode of Carrying Out the Invention

With reference to Fig. 1, a robot to which a robot operating method according to an embodiment of the present invention is applied will be explained.

The robot comprises a robot control apparatus 10 which is basically the same in construction as the prior art control apparatus, and a robot body 30 having an arm assembly and a tool assembly (none of which is shown) for performing desired working to a working subject 40 under the control of the control apparatus 10. The robot body 30 is designed, for instance, such that a robot tool is movable along X- and Y-axes of a tool coordinate system, and is rotatable with respect to an axis extending in parallel to a Z-axis of the tool coordinate system, with the position of the distal end of the tool kept unchanged. Further, the robot is so designed, for instance, as to perform the working to workpieces (working subjects) 40, which are sequentially transferred onto an assembly line, at plural working positions on each workpiece.

The control apparatus 10 comprises a microprocessor (hereinafter referred to as CPU) 11, a ROM 12 storing therein a control program, and a RAM 13 for storing a robot operation program and for temporally storing data and arithmetic results. The

control apparatus 10 further comprises an axis controller 14 which includes an interpolation circuit (not shown), an interface 16 connected to the working subject (assembly line) 40, an input/output circuit 17, a manual data input device (hereinafter referred to as CRT/MDI) 19 with a CRT display device, and a teaching pendant 20. The aforesaid elements 12 - 20 are respectively connected to the CPU 11 through busses 21. In addition, the control apparatus 10 includes servo circuits 15 connected to the axis controller 14 for drivingly controlling individual servomotors (not shown) of the robot body 30. A remote operation board 18 for supplying external signals is connected to the input/output circuit 17.

The robot is so arranged as to be operated in either one of automatic and manual operation modes. In this connection, the remote operation board 18 is arranged to generate first to sixth external signals for driving the robot tool during the manual operation, and a seventh external signal for restarting the automatic operation. The first to fourth external signals correspond to tool movement toward positive X-axis direction, negative X-axis direction, positive Y-axis direction, and negative Y-axis direction, respectively. The fifth and sixth external signals correspond to tool rotation to positive and negative directions, respectively. The control apparatus 10 and the robot body 30 are so arranged as to move or rotate the tool at a predetermined speed, which is parameter-set previously, in response to supply of an arbitrary one of the first to sixth external signals during the manual operation. In relation to the below-mentioned various processes associated with an operating mode selection and a manual adjustment, a predetermined

command code "S89, b, n" and a predetermined position correcting command code G45 are employed.

In the following, an operation of the robot constructed as mentioned above will be explained with reference to Figs. 2 and 3.

First, an operator operates the teaching pendant 20 and the CRT/MDI 19 to create a robot operation program. During the preparation of the robot operation program, the predetermined command code "S89, b, n" (S code) and the predetermined position correcting command code G45 (G code) are respectively inserted into appropriate locations of the program. For instance, the S code is inserted into a block next to a block which contains therein a move command toward a first teaching point, and the G code is stated together with each of teaching data respectively associated with a second and later teaching points. The program thus created is stored in the RAM 13. Alternatively, a robot operation program created previously may be stored in the RAM 13 through the input device (not shown).

During a playback operation of the robot in its automatic operating mode, the CPU 11 executes the robot operation program read out from the RAM 13, to thereby drive the servomotors for the individual axes of the robot body 30 through the axis controller 14 and the servo circuits 15. As a result, the robot tool moves to the first teaching point. When the CPU 11 reads out the predetermined command code "S89, b, n" from the robot operation program (step S1 of Fig. 2) after completion of the movement to the teaching point, the CPU changes the automatic operating mode to the manual operating mode (step S2).

During the manual operation, the operator operates

the remote operation board 18, at step S3, to perform manual adjustment so as to accurately position the robot tool at a fist working position A (Fig. 3) on the workpiece 40, which is generally positioned on the assembly line with a certain error, i.e., so as to compensate for positional dislocation, attributable to positional dislocation of the workpiece, of the first teaching point from the working position A with which the first teaching point should primarily coincide. As a result of the board operation, a corresponding one or ones of the first to sixth external signals are supplied from the remote operation board 18 to the control apparatus 10, whereby the robot body 30 is operated under the control of the control apparatus 10 so that, generally, the tool is moved along the X- and Y-axes and rotated around the axis parallel to the Z-axis, to be positioned at the first working position A.

After completion of the positioning, the operator operates the remote operation board 18 so as to supply the seventh external signal b to the control apparatus 10. When the CPU 11 determines the supply of the signal b at step S4, the CPU calculates correction data (4 X 4 conversion matrix) indicative of a manual adjustment amount which is associated with the tool movement and rotation from the first teaching point to the first working position A. Then, the CPU causes the RAM 13 to store the correction data at its storage region for storing an n-th group of offset data (step S5). Whereupon, the robot working is carried out at the first teaching point A after the manual adjustment (the first working position).

After completion of the robot working, when the CPU 11 reads out the position correcting command code G45, associated with the second teaching point B' (Fig.

3) from the operation program (step S6), the CPU carries out position correction associated with the second teaching point B' by the use of the correction data (conversion matrix) which is read out from the RAM 13 (step S7), and then causes the robot tool to move to the thus corrected teaching point B (step S8). In this manner, the tool is moved to the corrected teaching point B which is determined on the basis of the correction data which varies in dependence on the results of the manual adjustment for compensating for the positional dislocation of the first teaching point, whereby the positional dislocation of the workpiece in relation to the second working position is also compensated. Then, the robot working is carried out accurately, while the dislocations of the third and later teaching points from the third working position C, etc., attributable to the positional dislocation of the workpiece are similarly compensated.

When all the robot working for the first workpiece 40 is completed, the second and later workpieces 40 are positioned on the assembly line in sequence, and then the robot working is carried out accurately in the same manner as that for the first workpiece.

The present invention is not limited to the aforesaid embodiment, but may be modified in various manners.

For instance, the position correction process, corresponding to steps S6 - S8 of Fig. 2, even for the first teaching point may be carried out prior to the manual adjustment process. Preferably, the correction data for the position correction is renewed on the basis of a history of the manual adjustments for respective workpieces each time the manual adjustment is carried out. In this case, during the robot working

associated with the second and later workpieces, the first teaching point is corrected in accordance with the results of the manual adjustment for the preceding workpiece, preferably, in accordance with a history of the manual adjustments for the respective workpieces up to the preceding workpiece. In general, the workpieces, which are sequentially positioned on the assembly line, for instance, are liable to be dislocated from the predetermined positioning location toward substantially the same direction by substantially the same amount. Thus, if the first teaching point is temporally corrected in accordance with the preceding manual adjustment results, etc., in this manner, a required amount of the manual adjustment for each of the second and later workpieces is reduced, so that efficiency of the the manual adjustment operation and hence efficiency of the robot working are improved.

Although in the embodiment the robot working to a single workpiece is effected at plural working positions of the workpiece, the present invention may be applied to that case in which the robot working to each workpiece is performed at a single working position of the workpiece. In this case, preferably, the G code is inserted before the S code as in the aforesaid modification of the present invention, so that the teaching point is temporally corrected in accordance with the result of the manual adjustment for the preceding workpiece, preferably, in accordance with the history of the manual adjustments for the workpieces up to the preceding workpiece, to thereby reduce the manual adjustment amount.

CLAIMS

1. A robot operating method, comprising steps of:

(a) operating a robot in a manual operation mode when a first command code is read out from a program during an automatic robot operation;

(b) restarting the automatic operation when a predetermined external signal is supplied during the manual operation, and calculating and storing a correction data indicative of a manual adjustment amount in the manual operation; and

(c) correcting a teaching data, read out from the program, in accordance with the correction data when a second command code is read out from the program after the restart of the automatic operation.

2. A robot operating method according to claim 1, wherein said robot is arranged to sequentially perform robot working to plural working subjects which are of the same kind with one another, said robot working to each working subject being performed at plural working positions of each working subject, and said steps (a) and (b) are executed only for a first working position of each working subject in accordance with the first command code which is inserted into the program in relation only to a first position of the plural working positions.

3. A robot operating method according to claim 2, wherein said step (c) is executed for a second and later working positions of said plural working positions of each working subject in accordance with said second command codes each of which is inserted into the program in relation to a corresponding one of the second and later working positions.

FIG.1

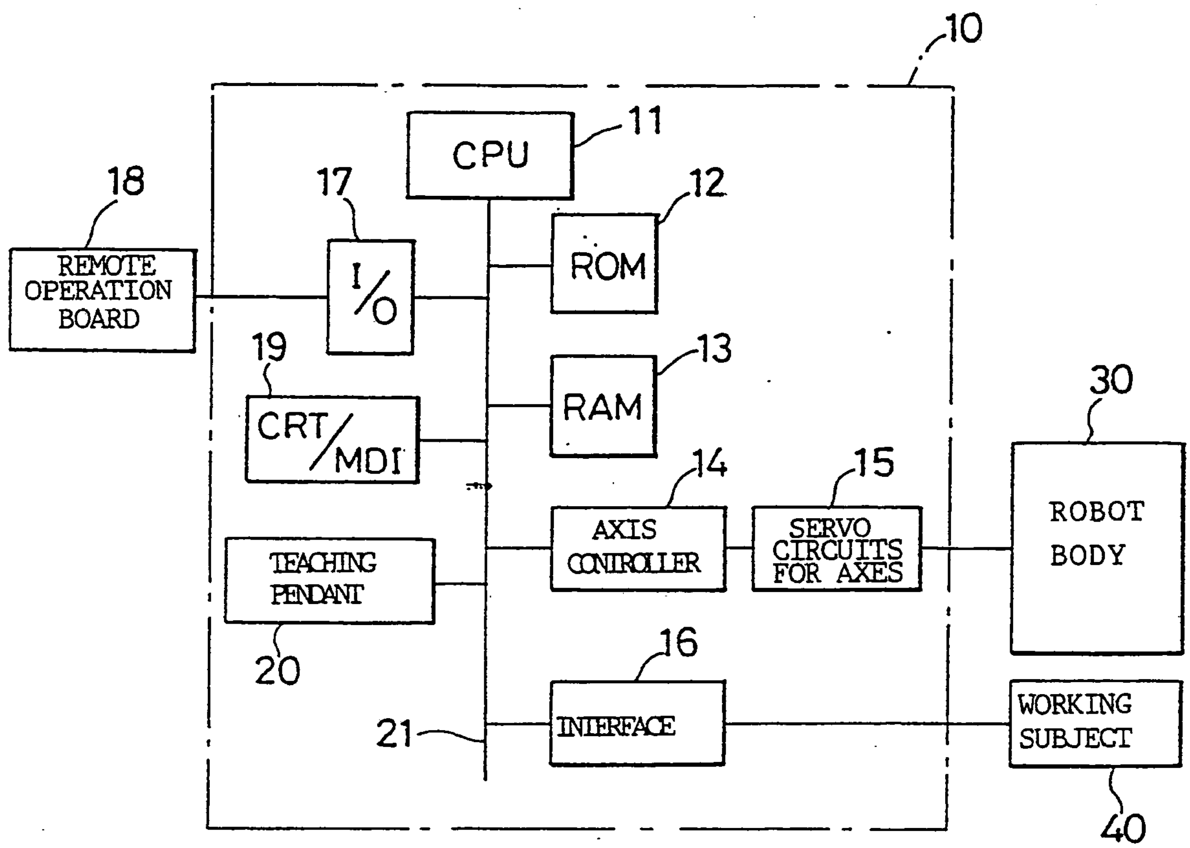

10
CPU
11
12
13
14
15
16
17
18
19
20
21
30
40
REMOTE OPERATION BOARD
I/O
ROM
RAM
CRT/MDI
AXIS CONTROLLER
SERVO CIRCUITS FOR AXES
ROBOT BODY
TEACHING PENDANT
INTERFACE
WORKING SUBJECT

FIG.3

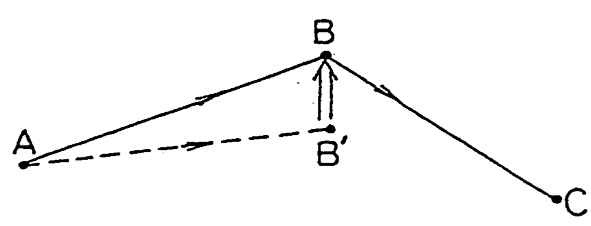
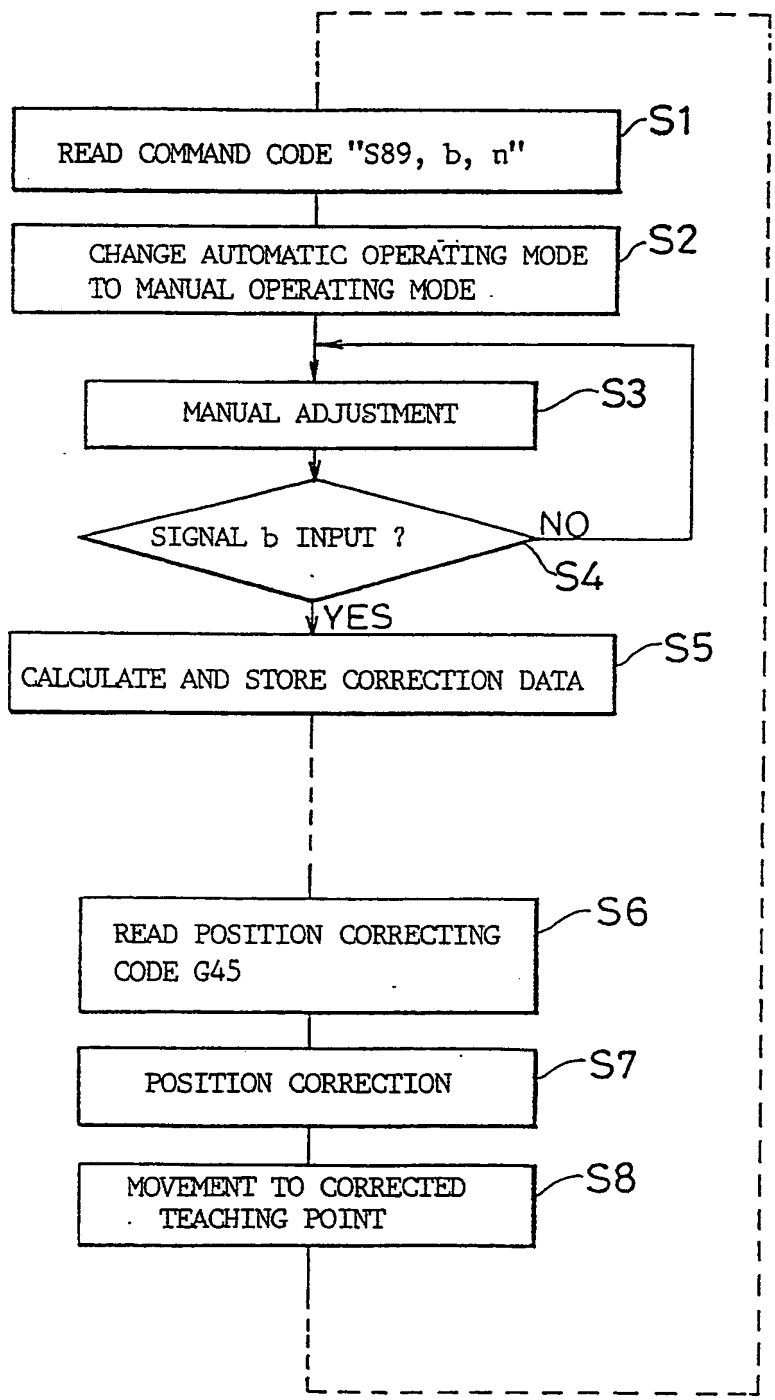

A
B
B'
C

FIG.2


READ COMMAND CODE "S89, b, n"
S1
CHANGE AUTOMATIC OPERATING MODE TO MANUAL OPERATING MODE
S2
MANUAL ADJUSTMENT
S3
SIGNAL b INPUT ?
NO
S4
YES
CALCULATE AND STORE CORRECTION DATA
S5
READ POSITION CORRECTING CODE G45
S6
POSITION CORRECTION
S7
MOVEMENT TO CORRECTED TEACHING POINT
S8

INTERNATIONAL SEARCH REPORT

International Application No PCT/JP89/01234

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int. Cl^5 B25J9/10, 9/16, G05B19/42

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC	B25J9/10 - 9/22, G05B19/42

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

Jitsuyo Shinan Koho 1926 - 1989
Kokai Jitsuyo Shinan Koho 1971 - 1989

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
Y	JP, A, 61-285506 (Tokico Ltd.), 16 December 1986 (16. 12. 86), Page 1, lower left column, lines 5 to 19 (Family: none)	1 - 3
Y	JP, A, 61-233806 (Mitsubishi Electric Corporation), 18 October 1986 (18. 10. 86), Page 1, lower left column, lines 5 to 12, column 3, upper left column, line 15 to upper right column, line 20 (Family: none)	1 - 3
Y	JP, A, 61-231604 (Hitachi, Ltd.), 15 October 1986 (15. 10. 86), Page 1, lower left column, lines 4 to 13 (Family: none)	1 - 3
Y	JP, A, 59-189415 (Hitachi, Ltd.), 27 October 1984 (27. 10. 84), & EP, A, 123,214	1 - 3

* Special categories of cited documents: [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
February 26, 1990 (26. 02. 90)	March 12, 1990 (12. 03. 90)
International Searching Authority	**Signature of Authorized Officer**
Japanese Patent Office	

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

Y	JP, U, 58-84882 (NEC Corporation), 8 June 1983 (08. 06. 83), Page 1, lower left column, lines 2 to 22 (Family: none)	1 - 3
A	JP, A, 58-87603 (Tokico Ltd.), 25 May 1983 (25. 05. 83), Page 1, lower left column, lines 5 to 15 (Family: none)	1 - 3
A	JP, A, 59-116810 (Hitachi, Ltd.), 5 July 1984 (05. 07. 84), Page 1, lower left column, lines 4 to 12 (Family: none)	1 - 3

V.☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE [1]

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1.☐ Claim numbers , because they relate to subject matter not required to be searched by this Authority, namely:

2.☐ Claim numbers , because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3.☐ Claim numbers , because they are dependent claims and are not drafted in accordance with the second and third sentences of PCT Rule 6.4(a).

VI.☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING [2]

This International Searching Authority found multiple inventions in this international application as follows:

1.☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2.☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3.☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4.☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☐ No protest accompanied the payment of additional search fees.